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Title page

Refraction in children: a comparison of two methods of accommodation control

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ABSTRACT

Purpose: The prevalence of refractive errors in children has been extensively researched. Comparisons between studies can, however, be compromised because of differences between accommodation control methods and techniques used for measuring refractive error. The aim of this study was to compare spherical refractive error results obtained at baseline and using two different accommodation control methods – extended optical fogging and cycloplegia, for two measurement techniques – autorefraction and retinoscopy.

Methods: Participants comprised twenty-five school children aged between 6 and 13 years (mean age: 9.52 ± 2.06 years). The refractive error of one eye was measured at baseline and again under two different accommodation control conditions: extended optical fogging (+2.00DS for 20 minutes) and cycloplegia (1% cyclopentolate). Autorefraction and retinoscopy were both used to measure most plus spherical power for each condition.

Results: A significant interaction was demonstrated between measurement technique and accommodation control method ($p = 0.036$), with significant differences in spherical power evident between accommodation control methods for each of the measurement techniques ($p < 0.005$). For retinoscopy, refractive errors were significantly more positive for cycloplegia compared to optical fogging, which were in turn significantly more positive than baseline, while for autorefraction, there were significant differences between cycloplegia and extended optical fogging and between cycloplegia and baseline only.

Conclusions: Determination of refractive error under cycloplegia elicits more plus than using extended optical fogging as a method to relax accommodation. These findings support the use of cycloplegic refraction compared with extended optical fogging as a means of controlling accommodation for population based refractive error studies in children.

KEY WORDS: refractive error, children, methodology, retinoscopy, autorefraction, cycloplegia, fogging technique

The prevalence of paediatric refractive errors has been extensively researched, with many studies reporting refractive error data for school age children (from 4 – 17 years),[1-11] as well as in pre-school age children (6 – 72 months).[12-16] Comparison between these studies is, however, potentially compromised because of differences in the accommodation control methods used (non-cycloplegia and cycloplegia) as well as the techniques used for measuring refractive error (autorefraction and retinoscopy).[4]

The gold standard for measuring refractive error in children's population studies is with cycloplegia,[17-20] due to its ability to control accommodation. Inadequate control of accommodation can impact refractive error measurements in children, particularly with regards to hyperopia.[6] Non-cycloplegic measurements, using either autorefraction or retinoscopy, have been shown to underestimate the hyperopic refractive state of a child; this underestimation is referred to as latent error.[21] Many studies have measured latent error and report values ranging from 0.1D to 2.0D.[21-24] High latent errors have been shown to be associated with higher levels of hyperopia and also vary according to the target and instrument design selected for the measurement of refractive error.[21]

However, there are a number of disadvantages associated with cycloplegia, including time, discomfort, cost, and inconvenience. Accordingly, cycloplegic refractions have not always been the method of choice in research settings, which creates a problem with population studies where comparisons are compromised by the different methods adopted to measure refractive errors.

Optical fogging provides an alternative method of measuring refractive error, where accommodation is controlled by adding positive lenses in front of the eyes, to relax accommodation.[21, 25-28] Studies have compared retinoscopy performed with optical fogging to cycloplegic retinoscopy, however, the method by which the optical fogging was performed was either not described,[5, 29] or the amount of fogging varied between studies: +1.50D fogging lenses were used in one study[24] whilst increasing amounts of plus lens power applied in a stepwise procedure were used in another.[21]

One method of optical fogging involves the use of additional plus lenses over the habitual refraction for an extended period of time to relax accommodation. In this instance, optical fogging should reduce visual acuity to no worse than 6/60, unless large astigmatic errors exist; and it has been suggested that up to 10 or 15 minutes may elapse before satisfactory relaxation of accommodation has occurred.[30] Accommodation could therefore theoretically be relaxed by the participant viewing a distance target for a 20-minute time period through +2.00D lenses. A 20-minute time period was nominated because it was considered a sufficiently conservative amount of time to relax accommodation,[30] whilst having the advantage of being shorter than the time required for the onset of cycloplegic agents. In addition, it does not have the inconvenience of paralysing the child's accommodation and dilating their pupils for several hours after testing, should it prove to be a viable alternative as an accommodation control method. This particular optical fogging technique that includes an extended period of adaptation to blur has not previously been compared with other methods of accommodation control such as cycloplegia.

In this study, we compared spherical refractive error results measured at baseline and using two different accommodation control methods: extended optical fogging and cycloplegia in children. Autorefraction and retinoscopy were used to measure the most plus spherical refractive power, with the aim of determining whether extended optical fogging was comparable to cycloplegia for either or both measurement techniques. If the extended optical fogging technique proved to be comparable to cycloplegia, it could provide an effective alternative, therefore minimising discomfort and disruption to school and leisure activities for children participating in these studies.

MATERIALS AND METHODS

Twenty-five school children (7 male, 18 female) aged between 6 and 13 years (mean age: 9.52 years ± 2.06) were recruited from the Queensland University of Technology (QUT) Optometry clinic database as well as family and friends of academic staff members of the school. All children had best-corrected visual acuities of 6/7.5 or better.

The study was conducted in accordance with the tenets of the Declaration of Helsinki and was approved by the Queensland University of Technology Human Research Ethics Committee. All participants and their guardians were given a full explanation of the experimental procedures. Written informed consent was obtained from both the participant and their guardian prior to involvement, with the option to withdraw from the study at any time.

Vision testing was undertaken at the QUT Optometry clinic, and all autorefraction and retinoscopy measurements (using a phoropter) were performed by one investigator who was an experienced optometrist (author SH). A research assistant contributed to the data collection process, as retinoscopy measurements were acquired under masked conditions. The research assistant altered the phoropter settings under instruction from the investigator, ensuring that the latter was unaware of the lens powers in the phoropter. It was not necessary to mask autorefraction results as it is an objective measure that could not be affected by inadvertent bias. In addition, knowledge of the autorefraction result could not affect retinoscopy outcomes as the investigator performing retinoscopy had no knowledge of the spherical power that had been randomly dialled into the phoropter by the research assistant and was therefore masked to the results of their own retinoscopy throughout data collection.

The refractive error of one eye was measured at baseline and then under two different accommodation control conditions: extended optical fogging (+2.00DS for 20 minutes) and cycloplegia (1% cyclopentolate). Autorefraction was performed first followed by retinoscopy at baseline and then for each of the accommodation control conditions.

An open-field autorefractor (Shin-Nippon SRW-5000) was used for all autorefraction measurements. This autorefractor uses an open-view arrangement, which enables unrestricted binocular view of a distance target.[31] It therefore differs from other autorefractors, which use automated fogging mechanisms to control accommodation. Automated fogging mechanisms have not been found to adequately control the patient's accommodation in some cases, and the fixation target may induce instrument myopia.[32]

Baseline. Baseline measurements of refractive error were completed for autorefraction and retinoscopy prior to performing extended optical fogging and cycloplegia.

Extended optical fogging. Participants who did not normally wear spectacles were required to wear +2.00DS lenses binocularly whilst watching a 20-minute video on a 15-inch screen at a working distance of 2 metres. This distance ensured that participants were able to view the screen with sufficient detail to maintain attention for the 20-minute period. As none of these participants were uncorrected hyperopes of greater than +1.00DS, the +2.00DS spectacles sufficiently fogged the 2m viewing target.

Participants who did wear spectacles had +2.00DS added to their spectacle correction and lenses of these powers were placed in a trial frame. The refractive power of the participant's spectacles was measured and compared against the non-cycloplegic retinoscopy to assess for under-corrected manifest hyperopia – to ensure adequate fogging was achieved with the addition of +2.00DS lenses. The participant viewed the same 20-minute video at a distance of 2 metres through these lenses.

The +2.00DS lenses were removed immediately before the autorefraction and retinoscopy measurements were performed and were put back on as the participant moved between tests, to ensure that no regression of the accommodative effect achieved with the fogging lenses occurred.

Cycloplegia. Cyclopentolate 1% administered as a spray to the closed eye-lid was used to achieve cycloplegia. The spray application has been shown to produce equivalent cycloplegia to eye drops.[33] The cycloplegic spray was administered provided the participant reported no history of allergic reactions to mydriatic agents, and the anterior chamber angle was shown to be open. After 20 minutes, if pupil reactivity was still present, a second spray was administered. Pupil reactivity and diameter were recorded between 25 and 55 minutes after the first spray. Cycloplegia was considered complete when the pupil was both non-reactive to light and had a minimum diameter of 6mm according to recommended protocols.[1, 34]

Autorefraction. The distance fixation target for autorefraction (performed in a 3 metre room) was a 6/150 symbol (plus sign) and was positioned such that the optical axis of the instrument and the participant's line of sight when viewing the target were aligned. The large fixation target of a black plus sign on a plain white wall was selected as it would not provide a strong stimulus for accommodation. The participant was seated comfortably with their chin on the chin-rest, head against the forehead rest, eyes level with the eye mark and viewed binocularly the fixation target through the window.

Five repeated measurements were performed on the selected eye and the mean was calculated (using most plus spherical power result).

Retinoscopy. Working distance lenses of +1.50D were used, whilst the participant viewed a 6/60 letter at 6m. With the spherical power dial masked, a research assistant randomly dialled in a spherical power, whilst the investigator neutralised the beam; this procedure was repeated five times. The mean of the most plus spherical power was calculated from the five repeated measurements.

Statistical analysis.

Statistical analysis was performed using SPSS 18.0 (SPSS Inc., Chicago, IL). For all statistical tests, a p-value <0.05 indicated a statistically significant difference. A clinically significant difference was considered to be ≥ 0.25D mean difference between the different methods.[35]

A 2 x 3 repeated measures ANOVA with the factors of measurement technique (2 levels: retinoscopy, autorefractor) and accommodation control (3 levels: baseline, extended optical fogging and cycloplegia) was conducted for the most plus spherical power results. Follow-up one way ANOVAs were conducted comparing accommodation control methods for each measurement technique, which included pair-wise comparisons adjusted for family-wise error using the Bonferroni method.

RESULTS

The range in refractive errors was -1.40D to +1.05D, median = +0.25D. Sixty percent of participants had brown irides, 32% had blue irides and the remaining 8% had hazel irides. There was no significant relationship between latent error (increase in hyperopic refractive error with cycloplegia) and iris colour ($F(2, 22) = 0.776$, $p = 0.473$).

Group mean data for the most plus spherical power results obtained at baseline and under the two accommodation control methods (extended optical fogging and cycloplegia) are presented in Figure 1 for both autorefraction and retinoscopy. Results from the 2 x 3 repeated measures ANOVA showed that there was a statistically significant interaction between measurement technique and accommodation control method ($F(2, 23) = 3.861$, $p = 0.036$).

Follow-up one way ANOVAs comparing spherical power as a function of accommodation control showed a significant difference between accommodation control methods for both measurement techniques (retinoscopy: $F(2, 23) = 7.004$, $p = 0.004$; autorefraction: $F(2, 23) = 17.382$, $p < 0.001$). Pairwise comparisons, adjusted for multiple comparisons (Bonferroni) demonstrated significant differences between all three conditions (baseline, extended optical fogging and cycloplegia) for retinoscopy. For the autorefraction measurements, there was a significant difference between cycloplegia and extended optical fogging, and also between cycloplegia and baseline; however there was no significant difference between baseline and extended optical fogging. Additionally the retinoscopy and autorefractor measurements were significantly different under cycloplegia (autorefraction resulted in a more positive spherical power, $t(24) = 3.033$, $p = 0.006$), but not at baseline or after extended optical fogging; mean differences (± standard deviation) between autorefraction and retinoscopy at baseline and under the two accommodation control methods were: 0.07D ± .45 (baseline), 0.11D ± .46 (extended optical fogging) and 0.27D ± .44 (cycloplegia).

DISCUSSION

This study has shown that determination of refractive error under cycloplegia elicits a relatively more positive spherical power than using extended optical fogging as a method to relax accommodation in school-aged children.

The most plus spherical outcomes obtained under cycloplegia were also more positive than baseline. As such, our results agree with those reported in other studies comparing cycloplegic and non-cycloplegic results, where the mean spherical power was also significantly less hyperopic without cycloplegia.[21, 24, 34, 36, 37] This, however, is the first study to compare cycloplegia with extended optical fogging. Theoretically, whilst extended optical fogging should be an effective method of accommodation control our results show it to be less effective than cycloplegia for this group of school-aged children. Although it has been reported that the fogging technique is a valid method of controlling accommodation for low levels of fogging,[28] another study found varying results with optical fogging.[38] Furthermore, in the first study,[38] as the level of fogging was increased, some participants maintained a relaxed and stable accommodative state, whilst some demonstrated increased accommodative activity and others decreased accommodative activity. This suggests that optical fogging may not provide a consistent method for controlling accommodation for moderate to high levels of fog. It is possible that the varying results found with optical fogging were a consequence of varying levels of latent hyperopia amongst the participants – resulting in different levels of fogging, and thus different effects on the accommodative state. One disadvantage of optical fogging (particularly in children) is that latent hyperopia may affect the refractive outcome if sufficient fogging is not ensured.

In the current study, it was found that there was a hyperopic shift in spherical power when measured with extended optical fogging compared with baseline. However, a significantly more hyperopic difference existed between the cycloplegic and extended optical fogging condition, suggesting that cycloplegia is the most effective method for controlling accommodation.

Interestingly, there was a significant interaction between accommodative control method and measurement technique, which is represented as the difference in slopes in Figure 1. Thus, for the cycloplegic condition only, autorefraction yielded marginally but significantly more positive results than did retinoscopy. This difference between the two techniques and the significant interaction are most likely the result of two factors: i) larger cylinder measurements were recorded with autorefraction compared with retinoscopy (autorefractor cylinder was more than retinoscopy cylinder in 24/25 participants) artificially elevating the most plus spherical results and ii) the propensity for the autorefractor to relatively underestimate plus under non-cycloplegic conditions thus creating a larger difference in spherical power from baseline to cycloplegia for autorefraction compared with retinoscopy.[21] The difference in room size between techniques also has the potential to have a minimal effect on baseline measurement differences. Our finding of greater cylinder powers measured with autorefraction compared with retinoscopy is in agreement with other studies.[39, 40]

One limitation of this study is the relatively small range of refractive error of the participants. It is possible that the true difference between cycloplegia and extended optical fogging may have been underestimated as it is has previously been shown that latent error increases with increasing refractive error.[21]

Although cycloplegic retinoscopy is commonly used to measure refractive error in children, it requires trained personnel to perform the technique. Autorefraction, for this reason, is often used in children's refractive error studies as it can be performed by untrained personnel. As such, it is useful to investigate whether autorefraction provides equivalent quality data to retinoscopy.[20] Many authors have reported on the repeatability of autorefraction and retinoscopy in children; with variable estimates reported in the case of retinoscopy.[24, 41-44] In one study conducted with 40 adult participants, the repeatability of retinoscopy under cycloplegia was poorer when compared with non-cycloplegic retinoscopy. The authors proposed that there was greater ambiguity in the retinoscopic reflex from a dilated pupil compared with a small pupil resulting in a reduction in the repeatability of the measurements.[42] This reported difference in the repeatability of retinoscopy between cycloplegic and non-cycloplegic measurements may not be the case in children, however, as the difference in pupil size between the dilated and non-dilated eye is less. It is also likely that the differences in the repeatability of retinoscopy between studies result from differences in skill level between retinoscopists, given that the accuracy of retinoscopy results are strongly reliant on the ability of the person performing the retinoscopy. Further investigations directly comparing the repeatability of autorefraction (open-field) and retinoscopy under cycloplegia are currently underway within this participant group to confirm a preferred method for determining refractive error in paediatric population studies.

In summary, this study has demonstrated that extended optical fogging is less effective than cycloplegia in controlling accommodation in school age children. This finding confirms that cycloplegic refraction methods should remain the gold standard for population based paediatric refractive error studies. The question of whether autorefraction or retinoscopy should be adopted as the technique of choice to measure refractive error under cycloplegic conditions remains unresolved as both techniques are frequently reported in the literature – the selection of one as the gold standard would be optimal, to enable inter-study comparisons of refractive error in children.

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FIGURE LEGEND

Figure 1: Mean most plus spherical power for cycloplegic and non-cycloplegic (baseline and extended optical fogging) measurements.